CHPs and HPs to balance renewable power production: Lessons from the district heating network in Stockholm

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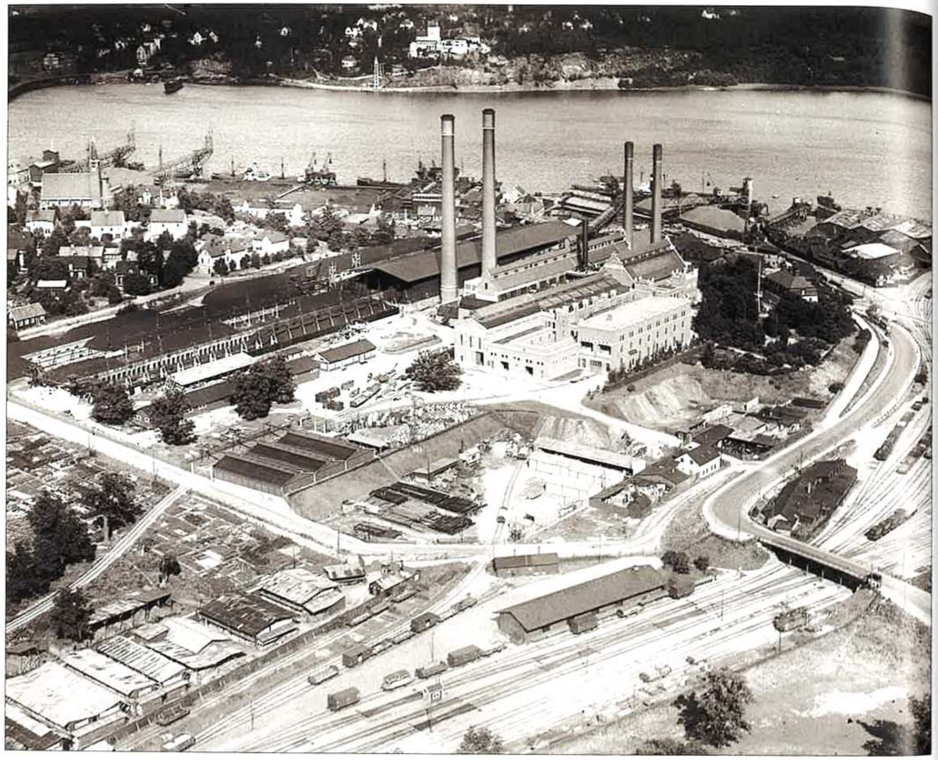
Fortum



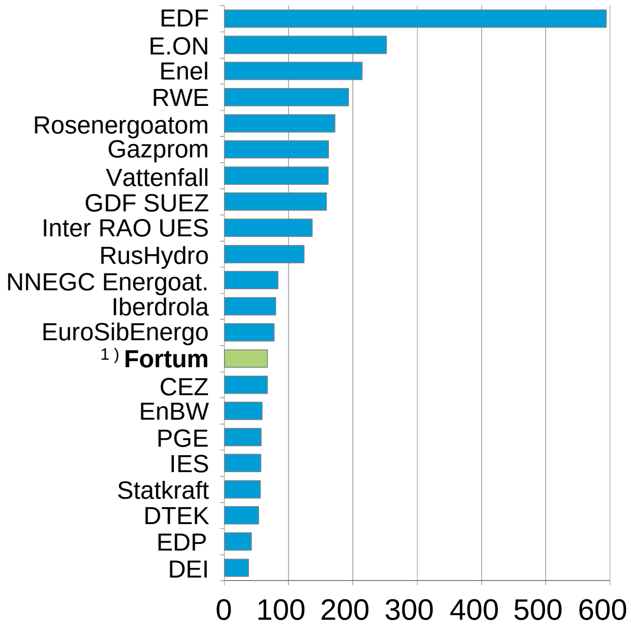
Next generation
energy company

Fortum

Fortum – a mid-sized European power generation player and a major producer in global heat

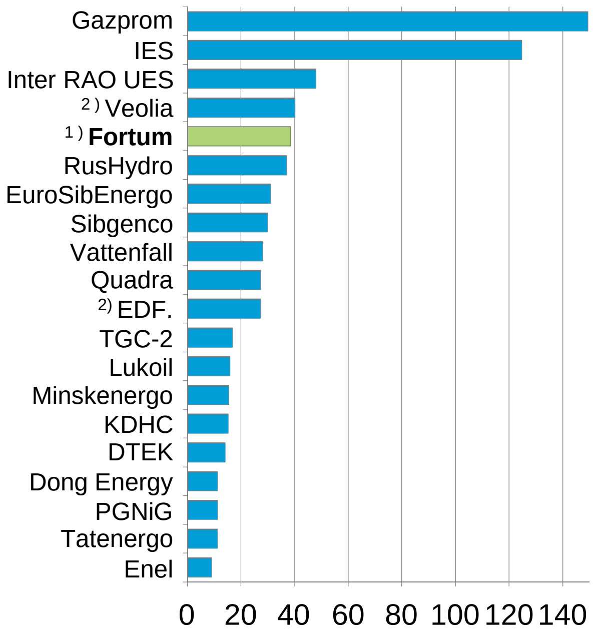
Power generation

Largest producers in Europe and Russia, 2013, TWh



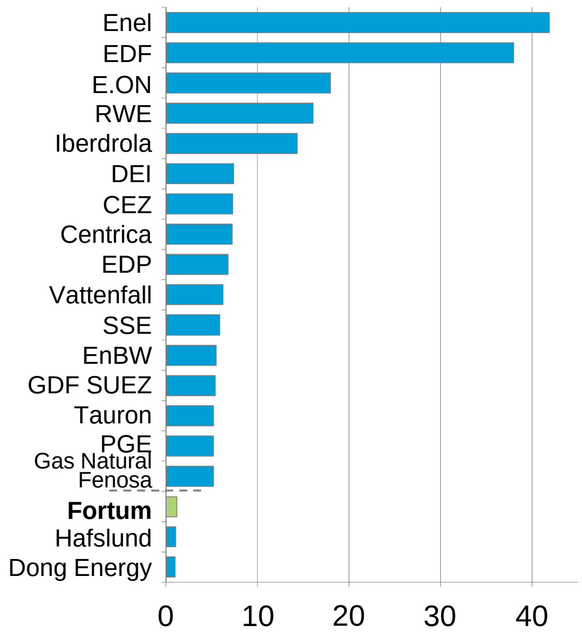
Heat production

Largest global producers, 2013, TWh



Customers

Electricity customers in EU, 2013, millions



1) Incl. Fortum's associated company Fortum Värme; power generation 1.3 TWh and heat production 8.2 TWh.
2) Veolia incl. Dalkia International and EDF incl. Dalkia's activities in France.
Source: Company information, Fortum analyses, 2013 figures pro forma, heat production of Beijing DH not available.

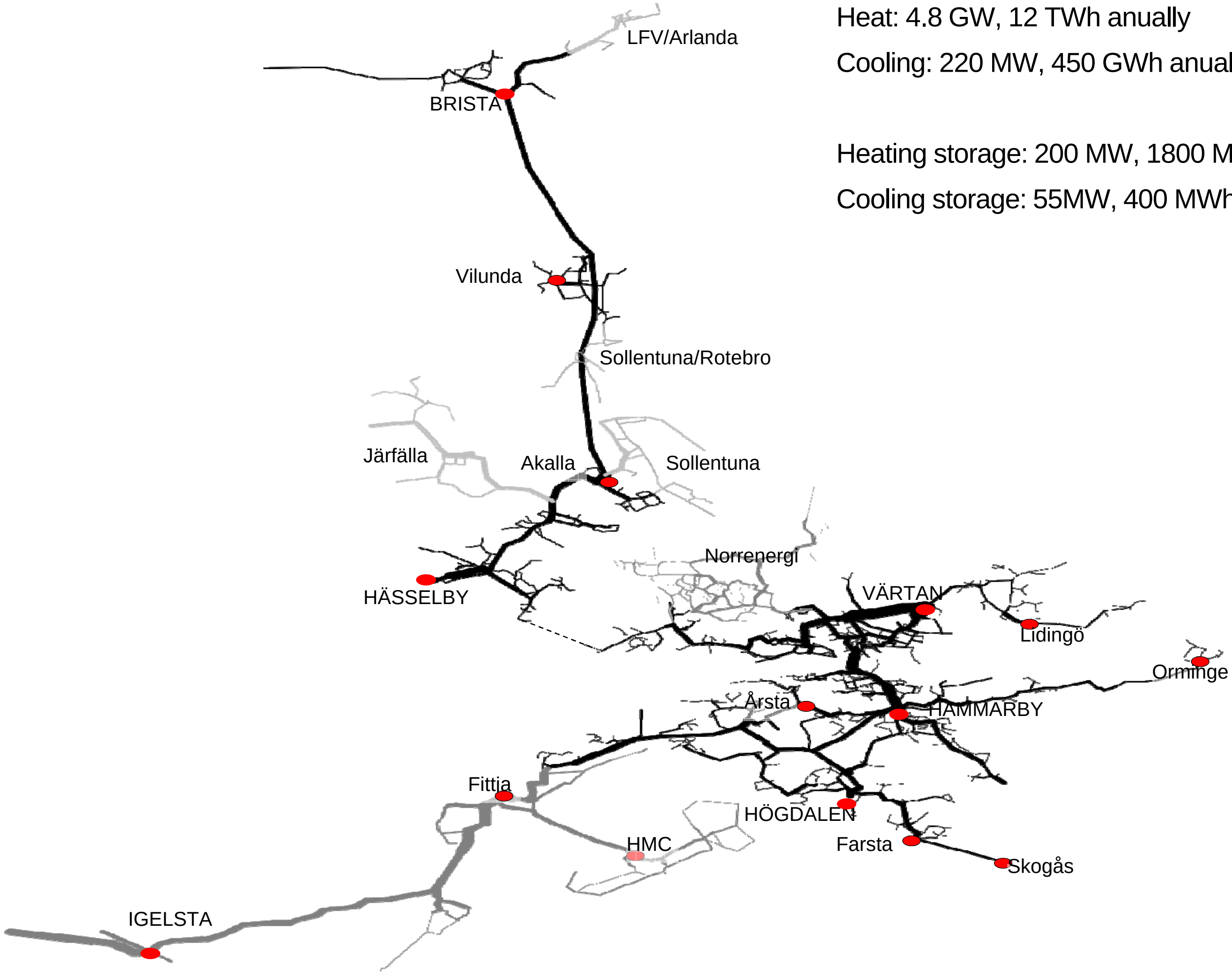
Research objective

In research much discussion on:

1. Utilizing CHP for balancing intermittent RES (Lund et al, 2014; Rinne and Syri. 2014; …).
2. Including large scale HPs into DH systems (Lauka et al, 2015; Lund et al, 2016…).

Fortum Värme has operated CHPs since 1970s and large scale HPs since 1990s → accumulated experience in these areas.

Stockholm district heating network



Heat: 4.8 GW, 12 TWh anually

Cooling: 220 MW, 450 GWh anually

Heating storage: 200 MW, 1800 MWh

Cooling storage: 55MW, 400 MWh

4 larger utilities cooperates:

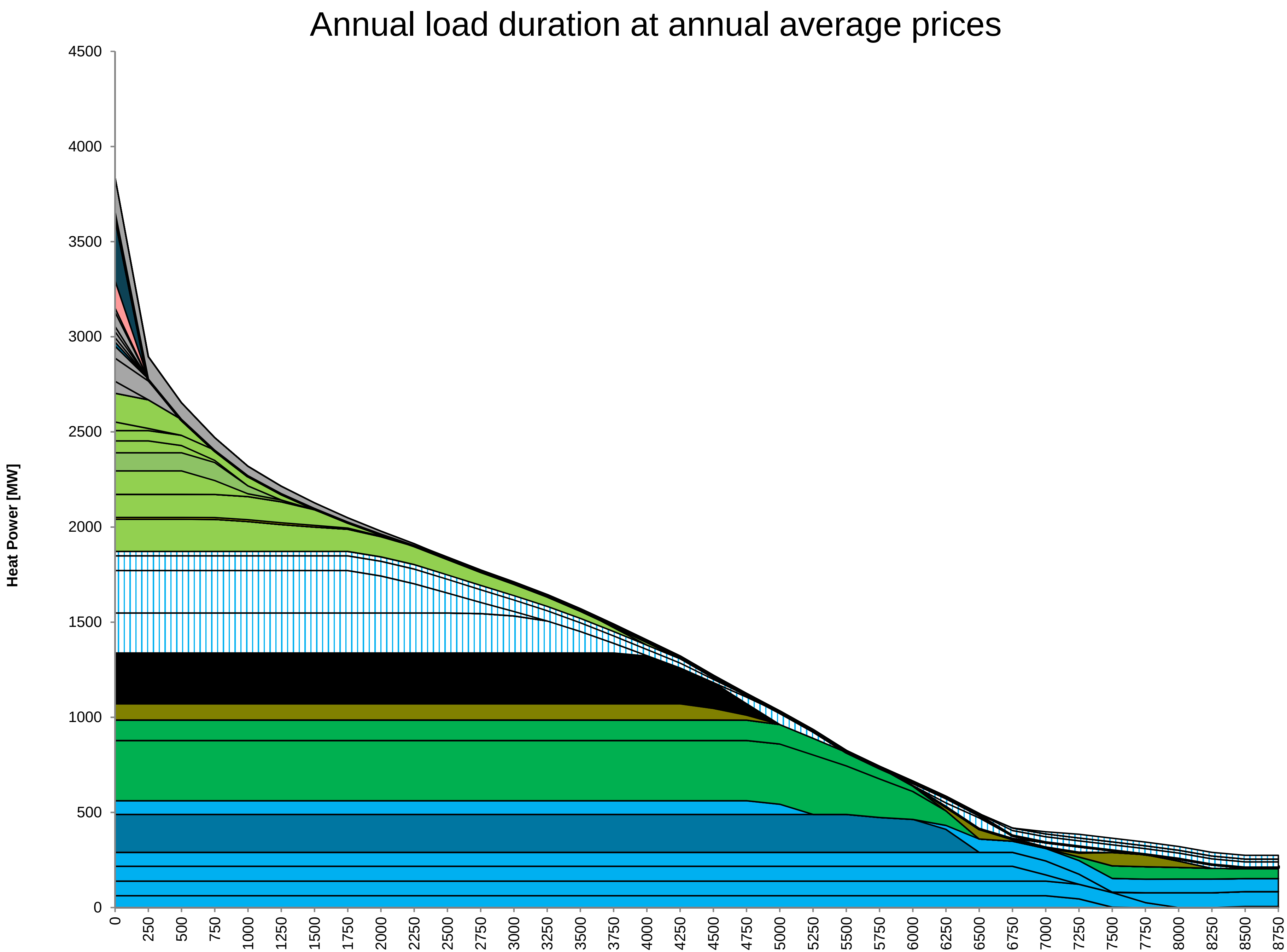
-Fortum Värme

-Söderenergi

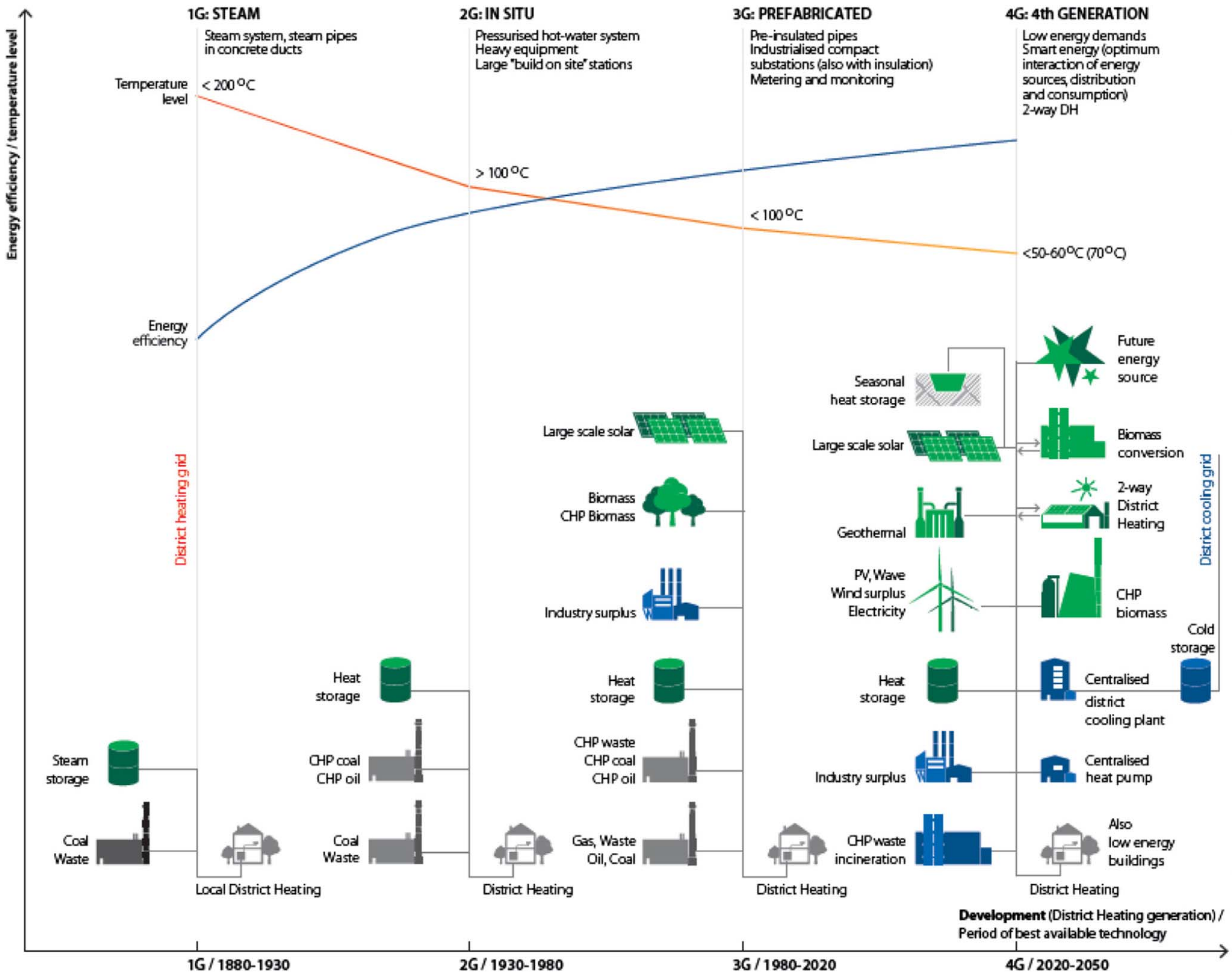
-Norrenergi

-E.On.

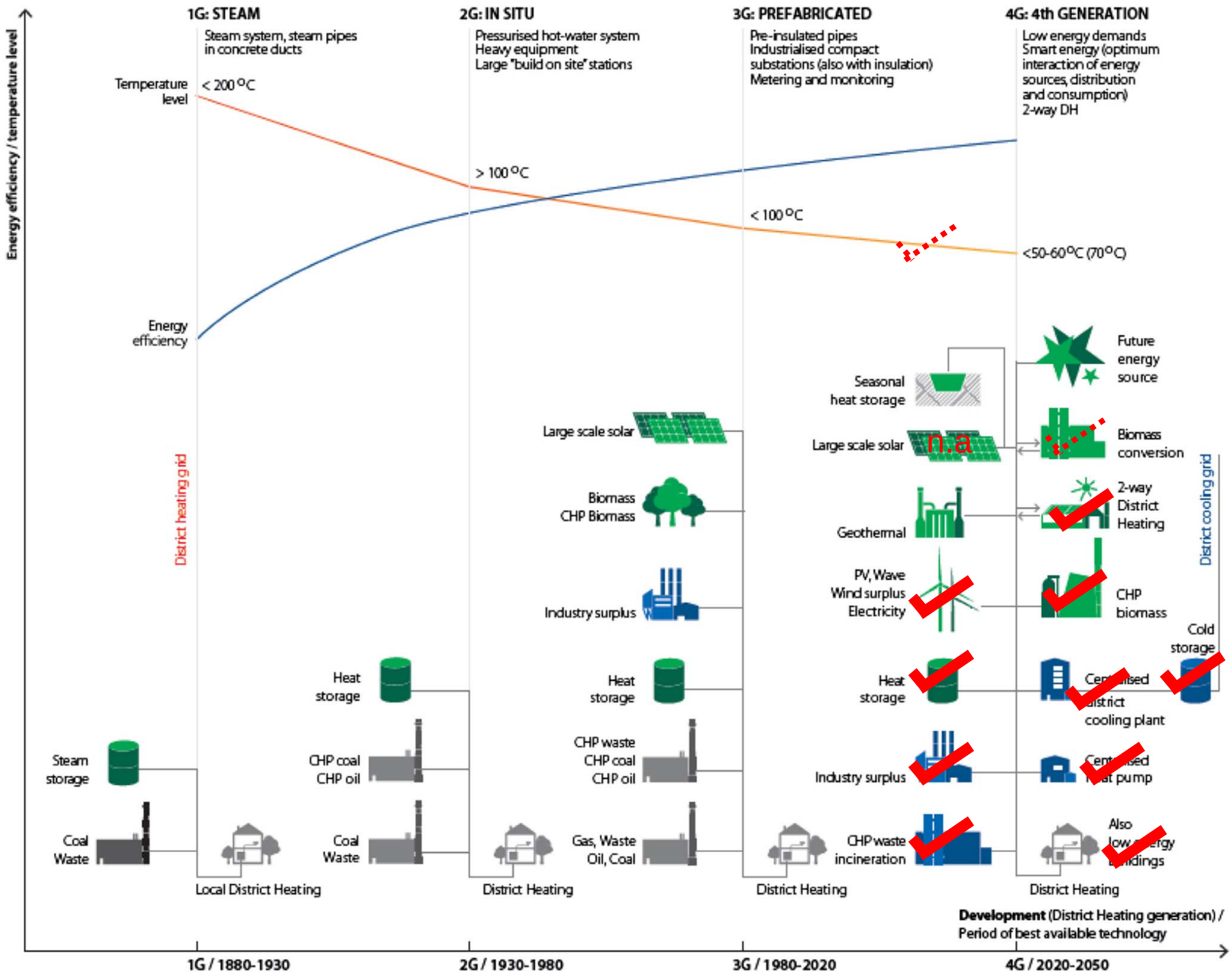
Open District heating model



Annual load duration at annual average prices
Heat Power [MW]
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
3750
4000
4250
4500
4750
5000
5250
5500
5750
6000
6250
6500
6750
7000
7250
7500
7750
8000
8250
8500
8750



1G: STEAM
Steam system, steam pipes in concrete ducts
2G: IN SITU
Pressurised hot-water system
Heavy equipment
Large "build on site" stations
3G: PREFABRICATED
Pre-insulated pipes
Industrialised compact substations (also with insulation)
Metering and monitoring
4G: 4th GENERATION
Low energy demands
Smart energy (optimum interaction of energy sources, distribution and consumption)
2-way DH
Energy efficiency / temperature level
Temperature level
< 200 °C
> 100 °C
< 100 °C
<50-60 °C (70 °C)
Energy efficiency
District heating grid
District cooling grid
Steam storage
Coal Waste
Local District Heating
Heat storage
CHP coal CHP oil
Coal Waste
District Heating
Large scale solar
Biomass CHP Biomass
Industry surplus
Heat storage
CHP waste CHP coal CHP oil
Gas, Waste Oil, Coal
District Heating
Seasonal heat storage
Large scale solar
Geothermal
PV, Wave Wind surplus Electricity
Heat storage
Industry surplus
CHP waste incineration
District Heating
Future energy source
Biomass conversion
2-way District Heating
CHP biomass
Cold storage
Centralised district cooling plant
Centralised heat pump
Also low energy buildings
District Heating
Development (District Heating generation) / Period of best available technology
1G / 1880-1930
2G / 1930-1980
3G / 1980-2020
4G / 2020-2050



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District Heating
Large scale solar
Biomass CHP Biomass
Industry surplus
Heat storage
CHP waste CHP coal CHP oil
Gas, Waste Oil, Coal
District Heating
Seasonal heat storage
Large scale solar
n.a
Geothermal
PV, Wave Wind surplus Electricity
Heat storage
Industry surplus
CHP waste incineration
District Heating
Future energy source
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CHP biomass
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4G / 2020-2050

Methodology

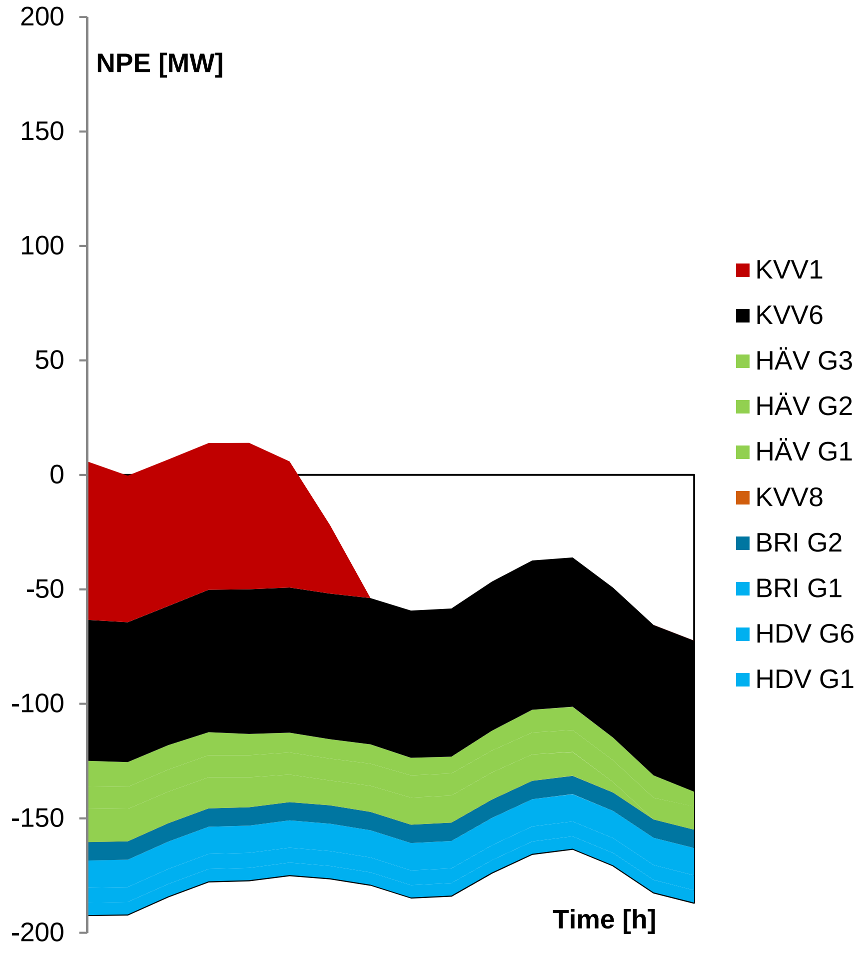
Analyzed period:

2015-01-01 to 2016-07-30.

Sources:

- Meassured turbine production and electric power consumption.
- Production planning reports.
- Noordpool spot prices for SE3
- UMM

NPE used to describe the Net Power Export from the Fortum Värme.



Fortum Värme CHPs and HPs

Name	Fuel	Technology	MW heat	MW power	Condensing mode
KVV8	Wood chips (2nd)	CFB	315	132	Yes
KVV6	Coal/Bio	2x PFBC	350	145	No
KVV1	Oil (bio/fossil)	Benson	330	220 (250)	Yes
Högdalen 1-4	Household waste	4x Roster	82	22,5	No
Högdalen 6	Industrial wood/waste	FBC	105	38	No
Hässelby 1-3	Wood pellets	3x water pipe	185	69	No
Brista 1	Industrial wood/waste	FBC	76	41	No
Brista 2	Household waste	BFB	50,5	20,5	No
Sum			*1178,5*	*556 (586)*	

Name	Heat source	COP	MW heat
Ropsten 1,2,3	Sea water / DC	3,4	251
Hammarby	Sewage treatment / DC	3,5	248
Nimrod	DC	3,3	36
Other	Sewage treatment / DC	3,3	125
Electric Boilers	n/a	0,98	(300)
Sum			*660 (960)*

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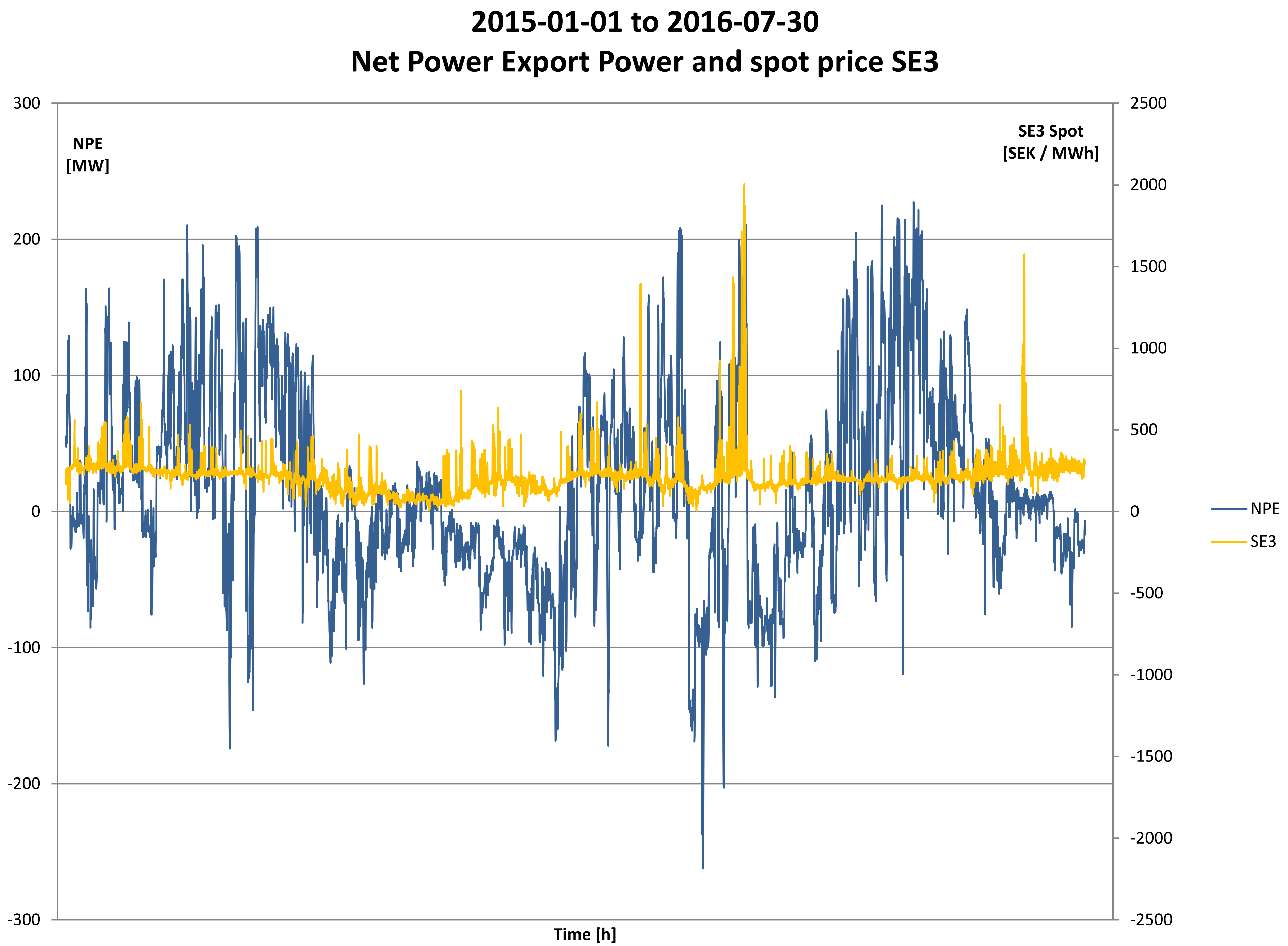
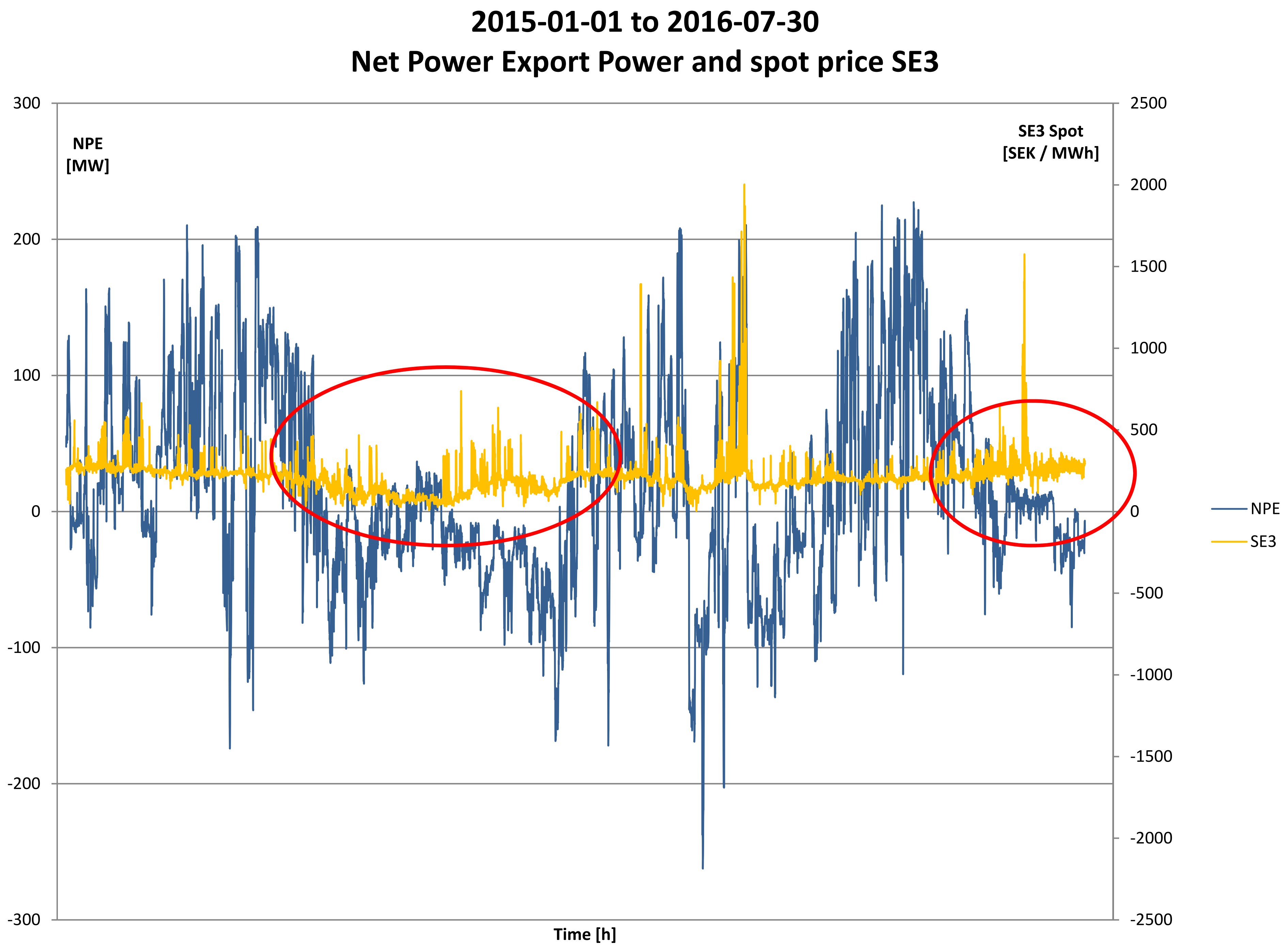
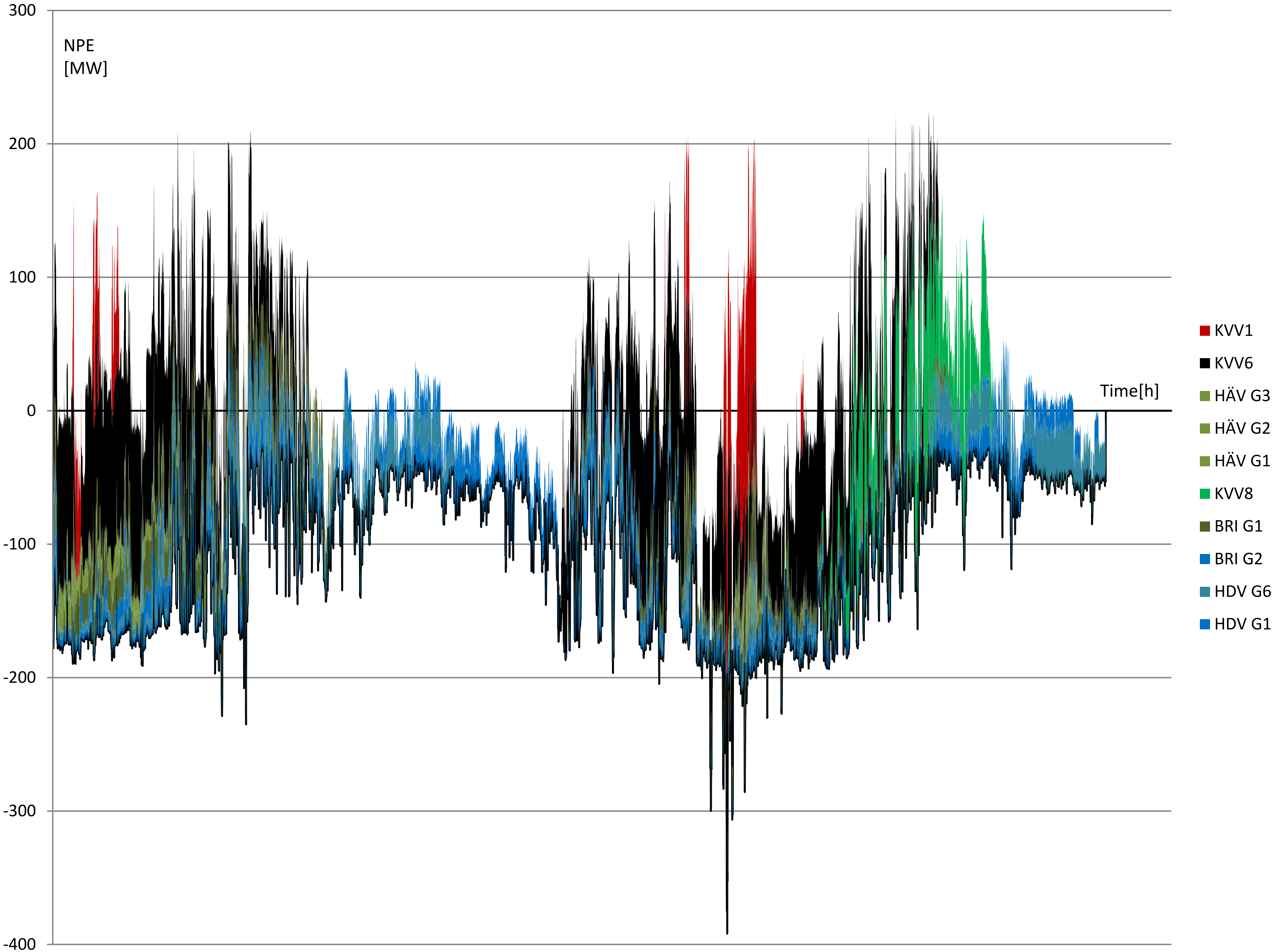
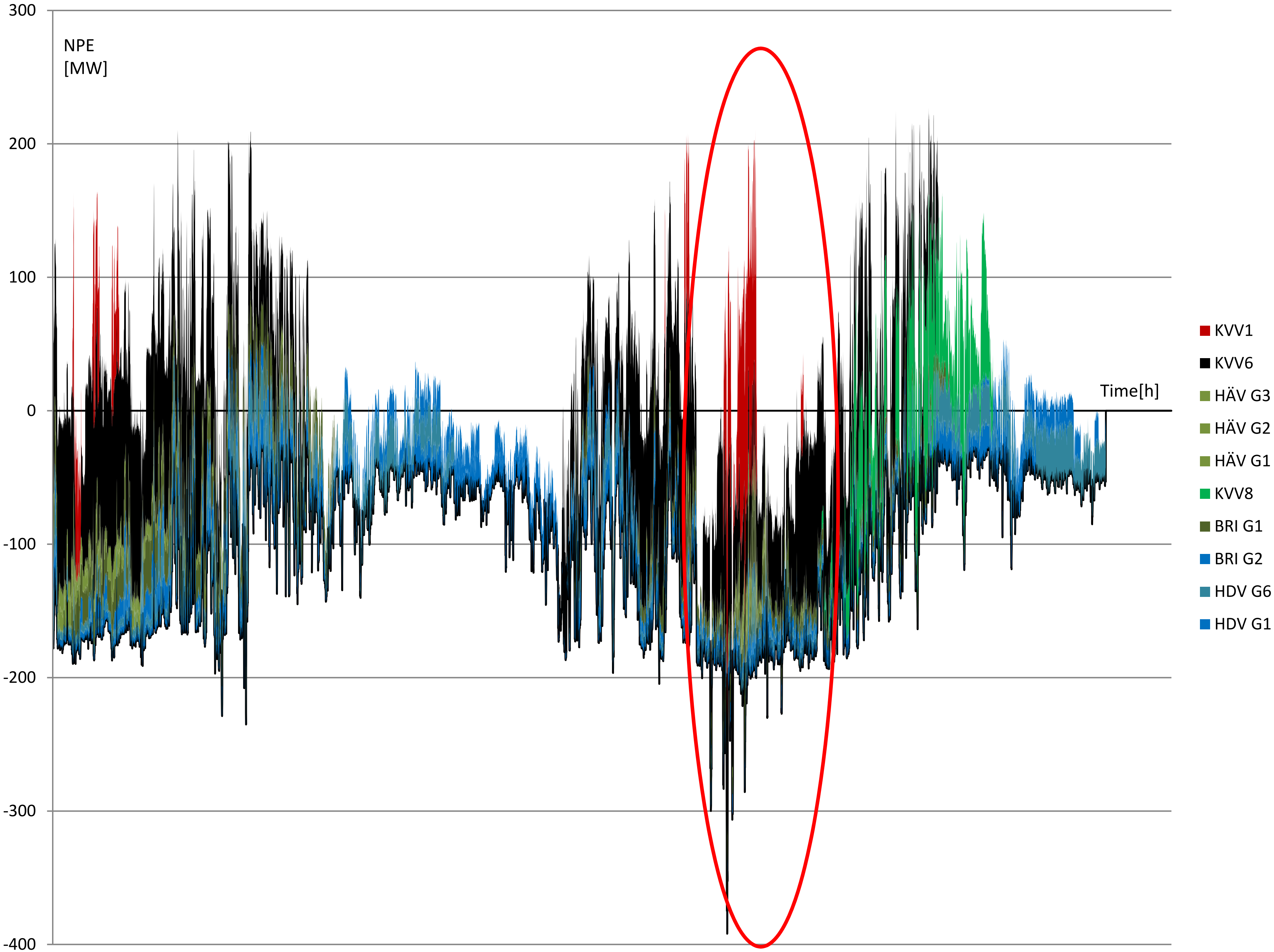

2015-01-01 to 2016-07-30
Net Power Export Power and spot price SE3
NPE
[MW]
SE3 Spot
[SEK / MWh]
300
200
100
0
-100
-200
-300
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
Time [h]
NPE
SE3

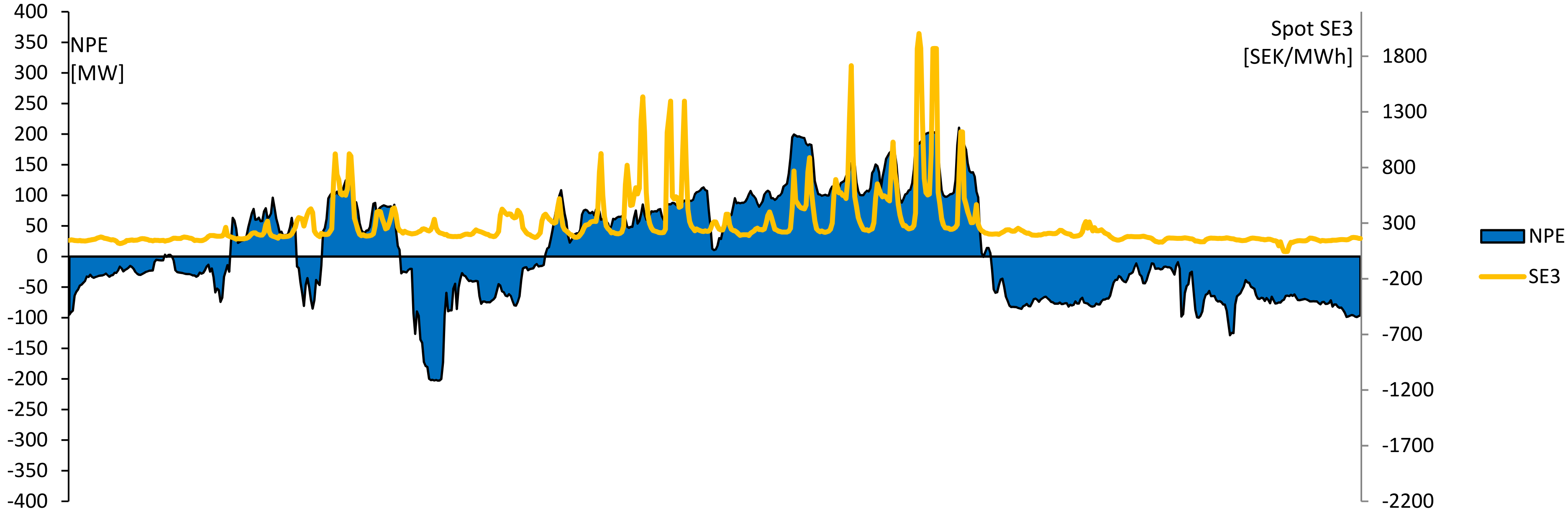

2015-01-01 to 2016-07-30
Net Power Export Power and spot price SE3
NPE
[MW]
SE3 Spot
[SEK / MWh]
300
200
100
0
-100
-200
-300
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
Time [h]
NPE
SE3



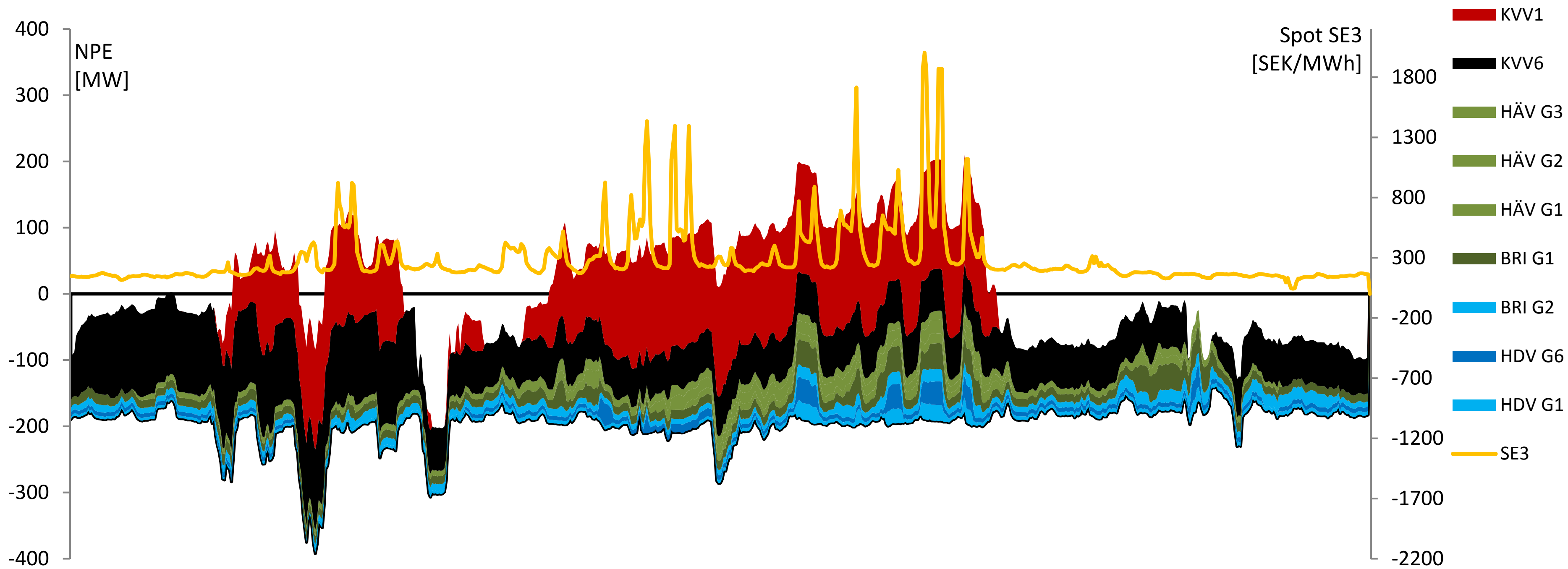
300
200
100
0
-100
-200
-300
-400
NPE
[MW]
Time[h]
KVV1
KVV6
HÄV G3
HÄV G2
HÄV G1
KVV8
BRI G1
BRI G2
HDV G6
HDV G1

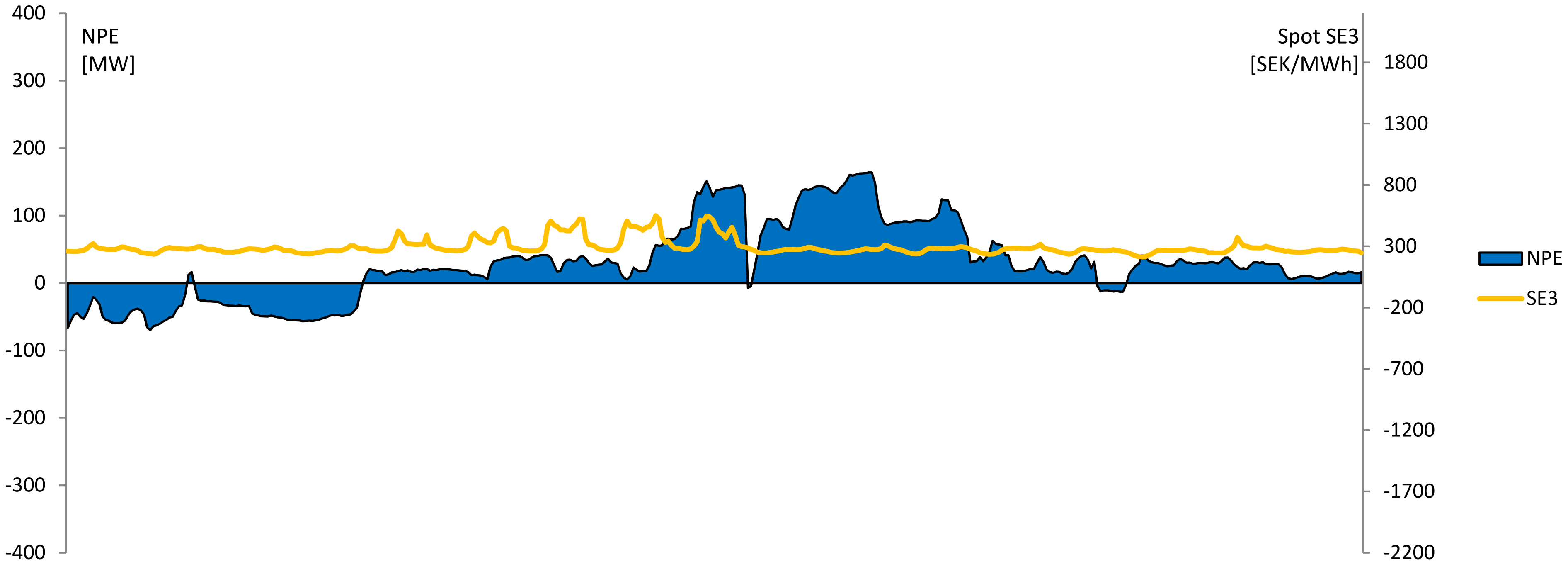


NPE
[MW]
300
200
100
0
-100
-200
-300
-400
Time[h]
KVV1
KVV6
HÄV G3
HÄV G2
HÄV G1
KVV8
BRI G1
BRI G2
HDV G6
HDV G1

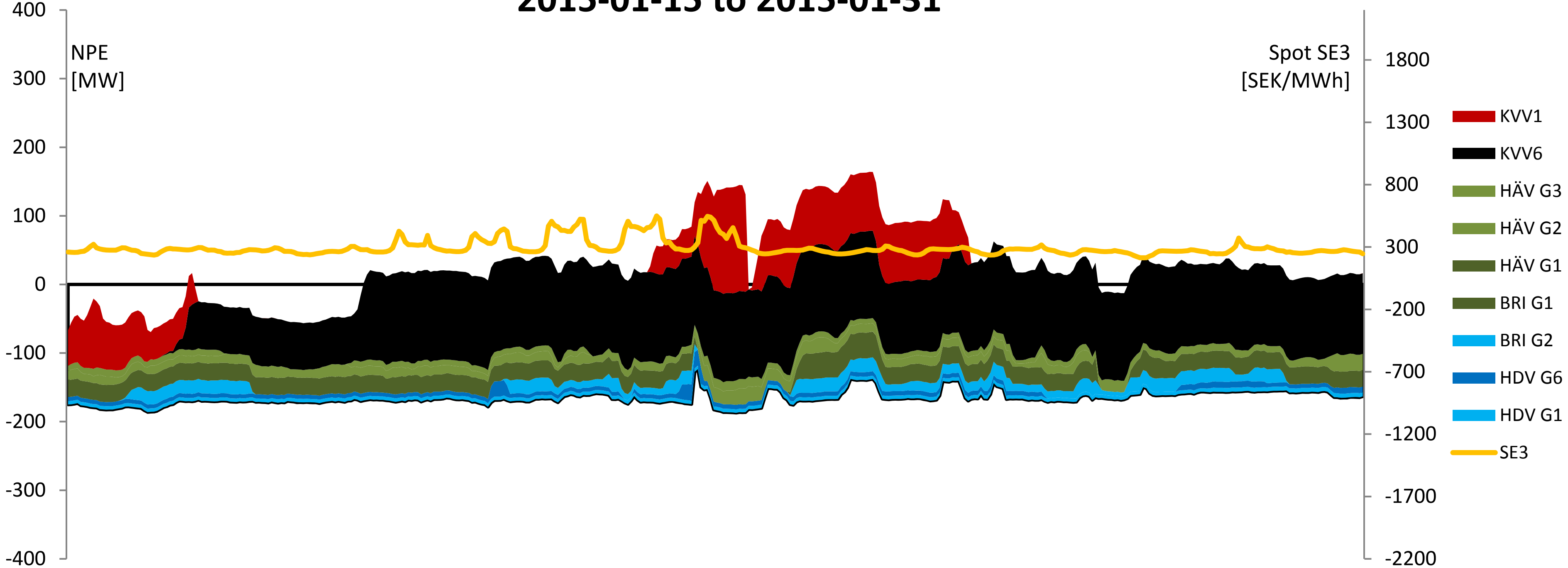


2016-01-01 to 2016-01-31





2015-01-15 to 2015-01-31



Conclusions

- NPE from -200 to 200 MW.
  - Heat only (turbine bypass) to co-generation used more than CHP and HP ramping for daily/fast variations
  - For cold periods and high prices CHP shift NPE to export.
- HPs only marginally used for following power prices. But has been used for intraday regulation.
- Combination of CHP and HP good for seasonal variations.
- Factors to enable more flexibility:
  - More short term storage to decouple heat, cooling and electric power generation.
  - Risk taking. Having a CHP ready instead of HOB if risk for high electric power prices.
- Possible for process optimization.
  - Dedicated supply of HP to low temp areas of the network
  - Utilize low return temperatures to increase CHP power production (alpha).

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